AN3269
Application note

Introduction to STM8L15x power saving modes using the STM8L-DISCOVERY I_{DD} measurement feature

Introduction

This application note introduces some of the power saving modes available in the STM8L microcontroller family. The STM8L-DISCOVERY has a built-in I_{DD} measurement feature that is used to demonstrate the real capabilities of the STM8L15x microcontroller's low power modes.

This application does not require any additional hardware. Once the STM8L-DISCOVERY is powered-up through a USB cable connected to the host PC, the application is ready to dynamically display the STM8L power consumption in each of the different modes selected by the user.

This software example comes preloaded with your STM8L-DISCOVERY and is readily accessible at application power-up.

Reference documents

- STM8L-DISCOVERY evaluation board user manual (UM0970)
- STM8L-DISCOVERY software user manual *Developing and debugging your STM8L-DISCOVERY application code* (UM0991)
- Application note *STM8L family power management* (AN3147)

The above documents are available at http://www.st.com.

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1 Application description

1.1 Hardware required

This application uses the STM8L-DISCOVERY on-board LEDs (green LD3 and blue LD4), the 6-digit/4-bar LCD glass display and the user push-button. No additional components are required.

1.2 STM8L-DISCOVERY hardware settings

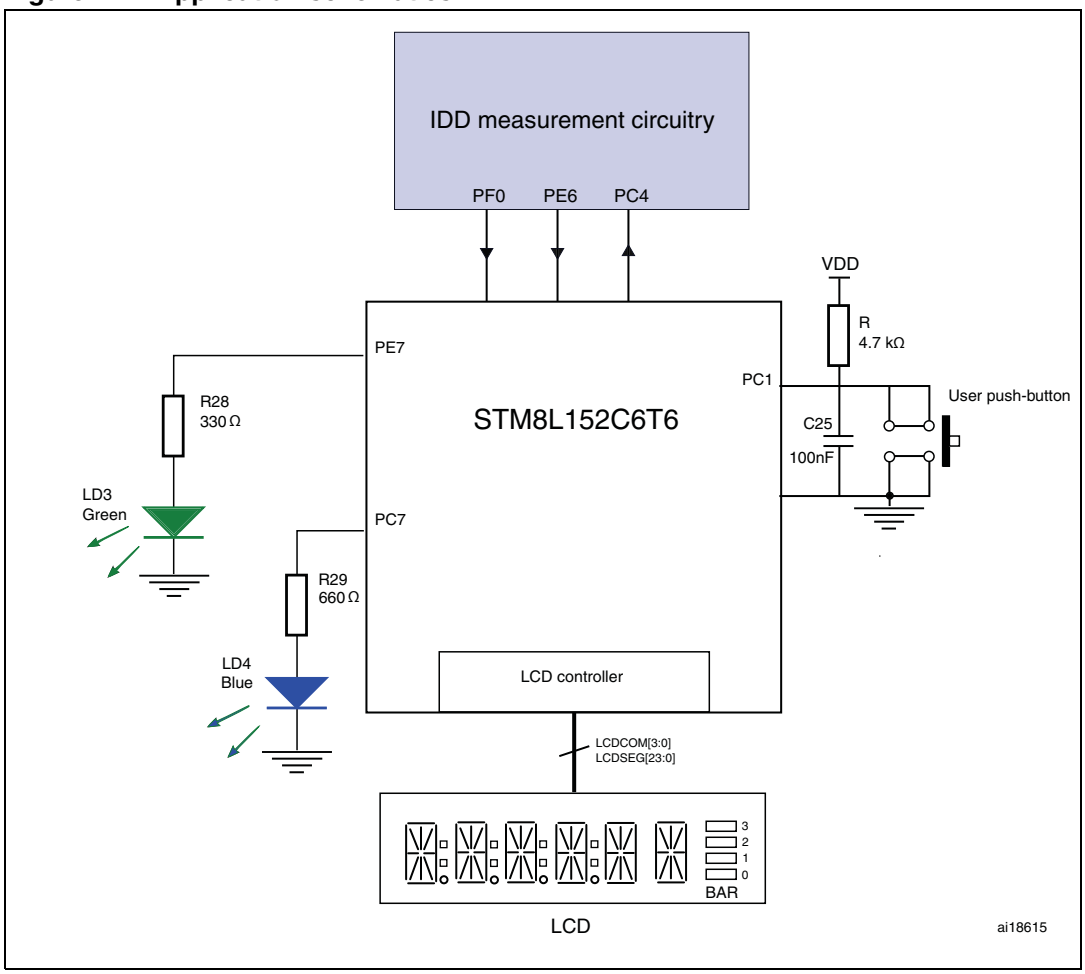
The I_{DD} jumper JP1 must be placed in position ON for standard operation (except for bias current record operation, see *Section 1.5.2*).

Note: All solder bridges SB11 to SB17 must be shorted (bottom side of STM8L-DISCOVERY).

1.3 Application schematics

Figure 1 shows the application electrical schematics.

Figure 1. Application schematics



1.4 Application principle

1.4.1 Overview

STM8L-DISCOVERY includes specific analog and logic hardware that is connected to STM8L152 microcontroller and which is intended to measure and display the supply I_{DD} current when the device is placed in different power consumption modes such as:

- Run mode
- LPR (Low power run mode) with LCD display ON
- LPR (Low power run mode) with LCD display OFF
- Halt mode

The user reads the value displayed on the STM8L-DISCOVERY's LCD panel, to know how much power the device is currently consuming.

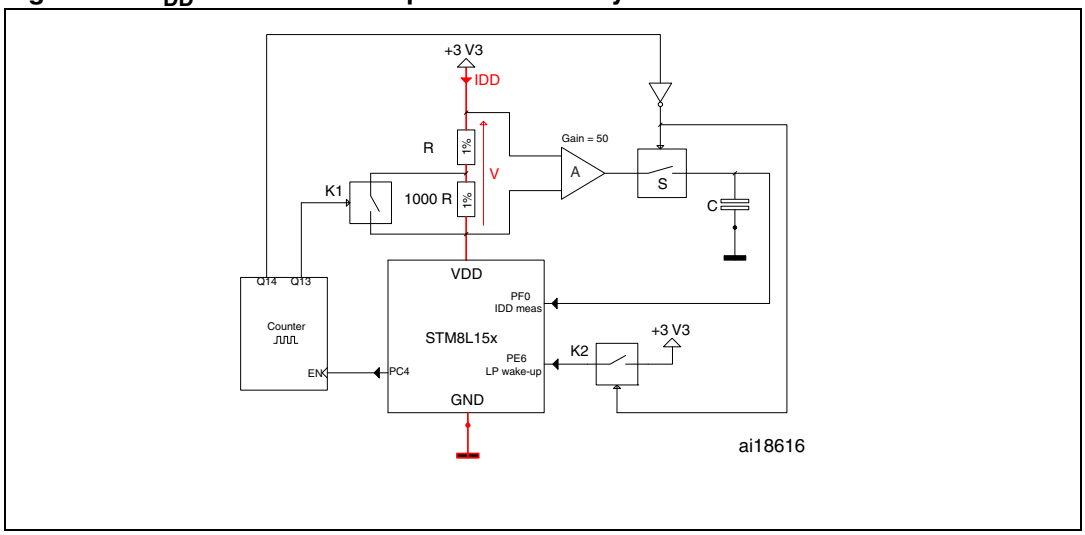
With this demonstration, you can obtain a precise and dynamic measurement of the STM8L152 supply current depending on the low power mode used.

It also includes a manufacturing test mode for performing a quick diagnosis of the STM8L-DISCOVERY related to this application example. See *Section 1.5.3: Manufacturing test* to have details regarding the test activation and meaning.

1.4.2 I_{DD} measurement principle

The STM8L-DISCOVERY I_{DD} measurement circuitry consists of measuring precisely the voltage value V at the terminals of a high precision serial resistor (1%) inserted between the +3V3 power supply and the V_{DD} pin of the MCU. Depending of the device power modes, the application uses R or [1000 + 1] x R as the equivalent resistor value by closing or opening K1. In Run mode, the current is in the range of mA, K1 is closed, and the equivalent resistor is R. In low power modes, the current is in the range of µA, K1 is opened, and the equivalent resistor is 1001 x R.

Figure 2. I_{DD} measurement equivalent circuitry



This resistor is placed in parallel to a high sense operational amplifier (A) with fixed gain that amplifies the voltage (V) present on resistors. A sample and hold stage is placed behind and

then is connected to an analog input of the MCU (PF0 I_{DD} Measurement) that finally converts the resulting voltage, image of the consumption current.

In low power modes only, a counter enabled by STM8L (PC4 pin) manages the measurement timing while the microcontroller is idle. The microcontroller is woken-up after a 150 ms delay controlled by the K2 switch.

While the microcontroller is in one of the power saving modes, a capacitor (C) is able to store the measurement charge so that the microcontroller can later give the value of Low power mode current consumption early on in the microcontroller wake-up phase (in the first 50 ms). Switch S is opened at device start-up in order to keep the charge collected in capacitor (C) intact while the microcontroller is in low power mode.

The current measurement precision is enhanced by taking into account the I bias current of its own operational amplifier. When JP1 is placed in OFF position (I_{DD} measurement circuitry disabled), a special test invoked by the user at device start-up measures this current value and stores it in the non-volatile memory. Once this value is stored in the device, it is deducted from the next I_{DD} measurement to compensate errors due to I bias current (see *Section 1.5.2: Bias current record*).

For additional information related to the I_{DD} measurement feature, please refer to STM8L-DISCOVERY evaluation board user manual (UM0970).

1.5 Getting started with the application

This STM8L-DISCOVERY example application has 3 application modes that can be run:

- Demo mode (I_{DD} measurement)
- Bias current record
- Manufacturing test

Demo mode is available at application power-up while the two other ones are called by the user according to a specific procedure that is detailed later in this chapter. However, for best performance, it is recommended to control and record the Bias current before starting precise I_{DD} measurement displays.

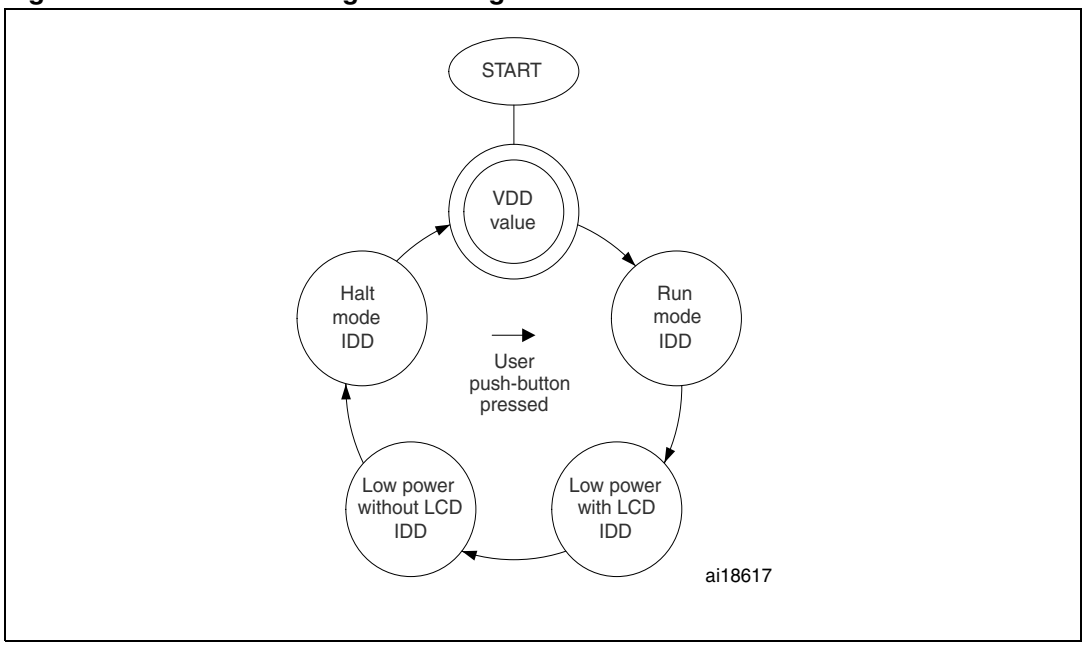
1.5.1 Demo mode (I_{DD} measurement)

Once the application is powered-up via the USB cable (or by external power supply), it starts displaying a welcoming message and then, after a few seconds, the value of the V_{DD} voltage applied to the STM8L device.

LD3 (green LED) and LD4 (blue LED) blink alternately. As soon as I_{DD} consumption values are displayed, both LEDs are turned off.

The User push-button allow you to change the functions as described in the state diagram in *Figure 3*. Each function consists of configuring the device with any required settings and then measuring and displaying the result on the LCD panel.

Figure 3. Function Change state diagram



BAR0 to BAR3 are used by the application to indicate ongoing measurements as shown in *Table 1*.

In order to save power during the I_{DD} measurement in *Low power run without LCD* and *Halt* modes, the LCD is switched off. Once the measurement performed it is then switched on to display the power consumption value.

Table 1. Bars and LCD display linked to functions

Function	Bars	LCD blinking
VDD		-
Run mode		-
Low power run with LCD		-
Low power run without LCD		X
Halt mode		X

1.5.2 Bias current record

This operation consists of storing in memory the value of the bias current inherent to operational amplifier A (see *Figure 2*) of your STM8L-DISCOVERY. The bias current value is taken into account for low power measurements in order to minimize measurement errors. Once recorded, this value does not need to be refreshed and is kept in non-volatile memory for future use. It is recommended to perform this operation when you start your evaluation in order to obtain the best precision.

This mode is only accessible at application power-up by executing the following actions in the order below:

- Switch OFF STM8L-DISCOVERY
- Place JP1 in OFF position (I_{DD} measurement disabled)
- Maintain USER push-button pressed while switching ON the STM8L-DISCOVERY
- At power on, a scrolling message “Bias Current” is displayed
- Release the USER push-button; the bias current value is displayed and immediately stored in non-volatile memory

Once this operation completed, replace JP1 in ON position so that the measurement circuitry connects again to STM8L152 (I_{DD} measurement enabled).

1.5.3 Manufacturing test

You can access this mode while Demo mode is running, by pressing the USER push-button for more than 3 seconds and by releasing it. This allows you to verify that the hardware modules needed by the STM8L-DISCOVERY for this example are working properly.

In this mode, application checks the LSE oscillator (Low Speed External), V_{DD} voltage value, I_{DD} RUN, I_{DD} HALT and LP (low power) I_{DD} currents. The currents are tested with lower and upper limits. For each test function, the application displays “OK” and the measured values when available. If all checks are successfully completed, then the message “TEST OK” is continuously displayed. If one of the tests fails, then the application alerts the user by continuously displaying the test name followed by “NO OK”.

To exit this manufacturing test, press the RESET button.

Note: Generally, if the manufacturing test is not successful, first check that JP1 is placed in the ON position and that solder bridges SB11 to SB17 are shorted. If errors are found in the Low power and Halt modes I_{DD} measurements, the bias current record operation should be performed again.

1.6 Low power modes

The low power modes used in this application example are:

- **Low power run mode (with or without LCD)**: In this mode the CPU and some of the peripherals are running. As selected, the LCD can be used or not. In the latter case, the LCD and the RTC clock are disabled to save power and GPIOs are placed in output push-pull configuration to limit consumption. During Low power run mode, the code is executed from RAM and CPU is clocked by the LSI oscillator. Flash and data EEPROM are stopped and the voltage regulator is configured in Ultra low power mode. The

microcontroller can be woken up from this power saving mode by an external event generated by a GPIO.

- **Halt mode:** CPU, oscillator and peripherals are stopped, device remains powered on. Voltage regulator is configured in Ultra low power mode. Device wakeup is done with external interrupt.

For further information, please refer to *STM8L family power management (AN3147)*.

2 Software description

2.1 STM8L peripherals used by the application

This application example uses the following STM8L peripherals with the settings described below:

ADC

ADC performs analog-to-digital conversions of the internal reference voltage (V_{DD} voltage display) and of the voltage coming from the operational amplifier that is the image of I_{DD} current.

- ADC resolution: 12-bit
- ADC conversion mode: single
- ADC sampling time: 9 cycles

TIM4

TIM4 is used to generating the delays needed for display or wait loops.

GPIOs

Port C and Port E are connected to the USER push-button and the LEDs.

- PC1 set as an input floating pin with interrupt (USER push-button)
- PC7 and PE7 set as an output push-pull pin (LD4 and LD3 LEDs respectively)
- PE6 set as an input floating pin with interrupt (I_{DD} Wakeup) with detection on rising edge
- During the low power modes, I/Os are placed in output push-pull to reduce power consumption except for a few pins related to the hardware interface (buttons, PF0 I_{DD} measurement pin, PE6 LP WakeUp pin and PC4)
- All Schmitt triggers on standard I/O pins are disabled to reduce power consumption
- The Schmitt trigger on PF0 is disabled in order to avoid measurement errors

LCD controller

The different functions available in the firmware library for LCD are used to initialize, clear, display strings and scrolling messages needed in the application code. For some low power mode measurements, the LCD controller is turned OFF to minimize the current consumption of STM8L152.

Clock

The HSI (high speed internal) 16 MHz oscillator is selected as clock source. The application manages the peripheral clocks depending on the selected power saving mode. When the device enters low power run mode, HSI is switched OFF and LSI acts as the main clock source until the device is woken-up by an external event. When exiting Low power run mode, the device switches the HSI oscillator back ON. On the other hand, LSE is switched ON during Manufacturing test mode (see *Section 1.5.3*).

2.2 STM8L15x standard firmware library configuration

The *stm8l*15x_conf.h file of the STM8L standard firmware library allows you to configure the library by enabling the peripheral functions used by the application.

The following statements must be present:

#include stm8l15x.h

#include stm8l15x_clk.h

#include stm8l15x_exti.h

#include stm8l15x_flash.h

#include stm8l15x_gpio.h

#include stm8l15x_lcd.h

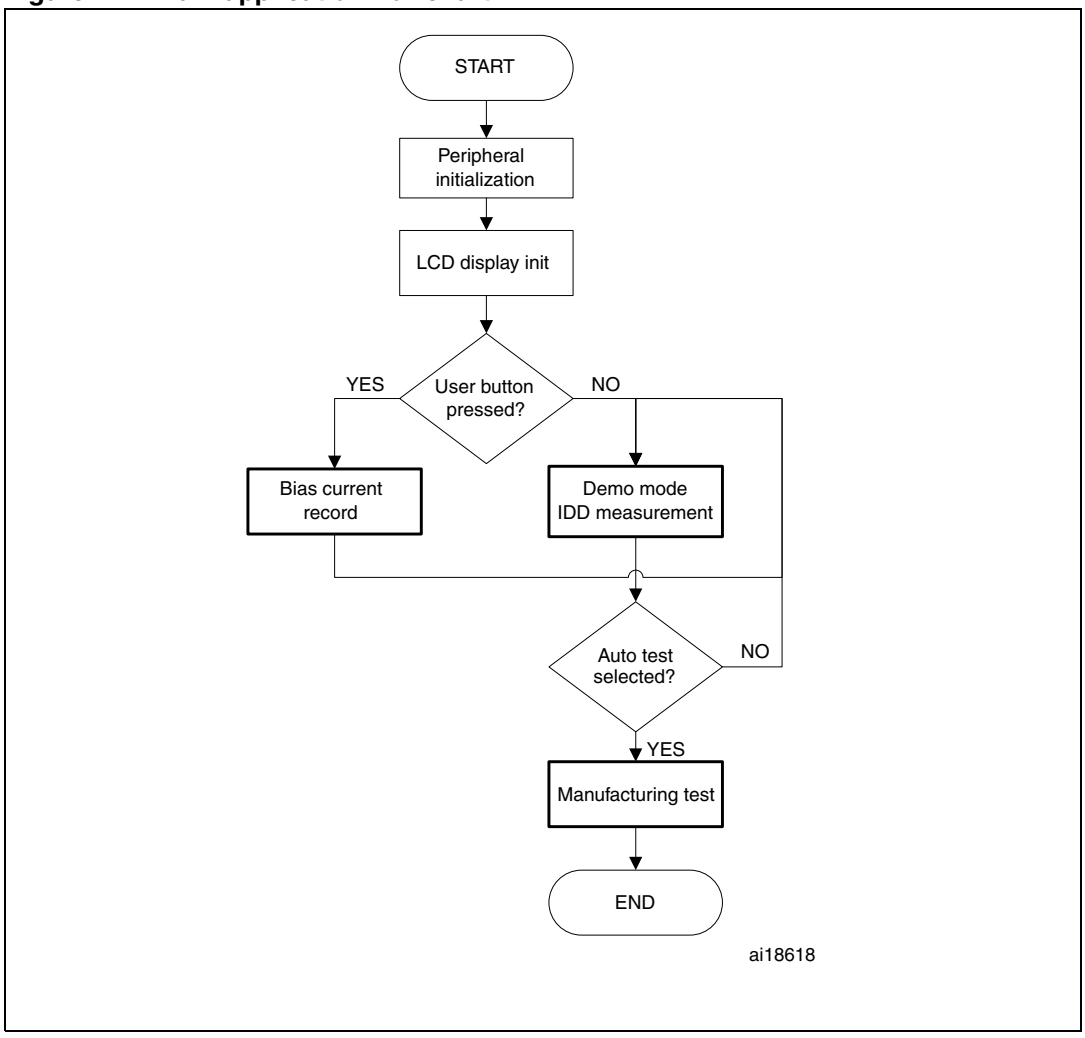
#include stm8l15x_rtc.h

#include stm8l15x_tim4.h

2.3 Application software flowcharts

2.3.1 Main application flowchart

Figure 4. Main application flowchart



As detailed in the flowchart, after starting the STM8L-DISCOVERY, the initialization of the peripherals and LCD display is performed and then the application immediately checks whether the USER push-button is pressed. If pressed, then the application goes to the Bias current record operation. Otherwise, the Demo mode (I_{DD} measurement) is automatically selected. If during Demo mode, the user presses the USER key for more than 3 seconds, then the application enters manufacturing test. To exit manufacturing test, the application needs to be restarted by pressing the RESET button.

2.3.2 Demo mode (I_{DD} measurement)

When Demo mode is launched, it starts displaying a welcoming message and then, after a few seconds, the V_{DD} value.

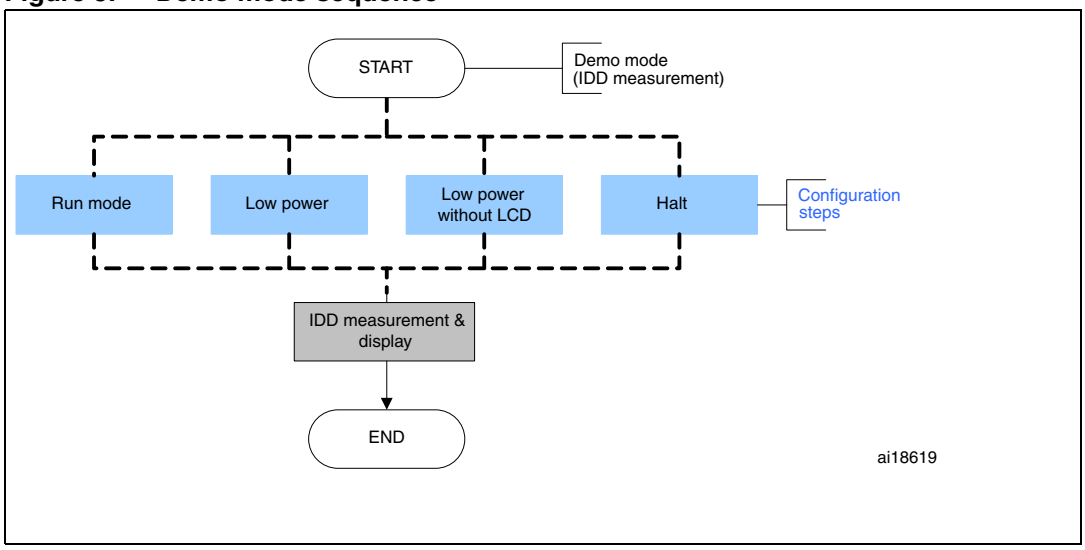
The user then selects one of the I_{DD} measurement functions by pressing successively on the USER pushbutton (as described in *Section 1.5.1*).

These functions are mainly divided in 2 steps:

- Configuring the device according to the selected power mode
- I_{DD} measurement and display (this part is common for all power modes)

The Demo mode sequence is as follows:

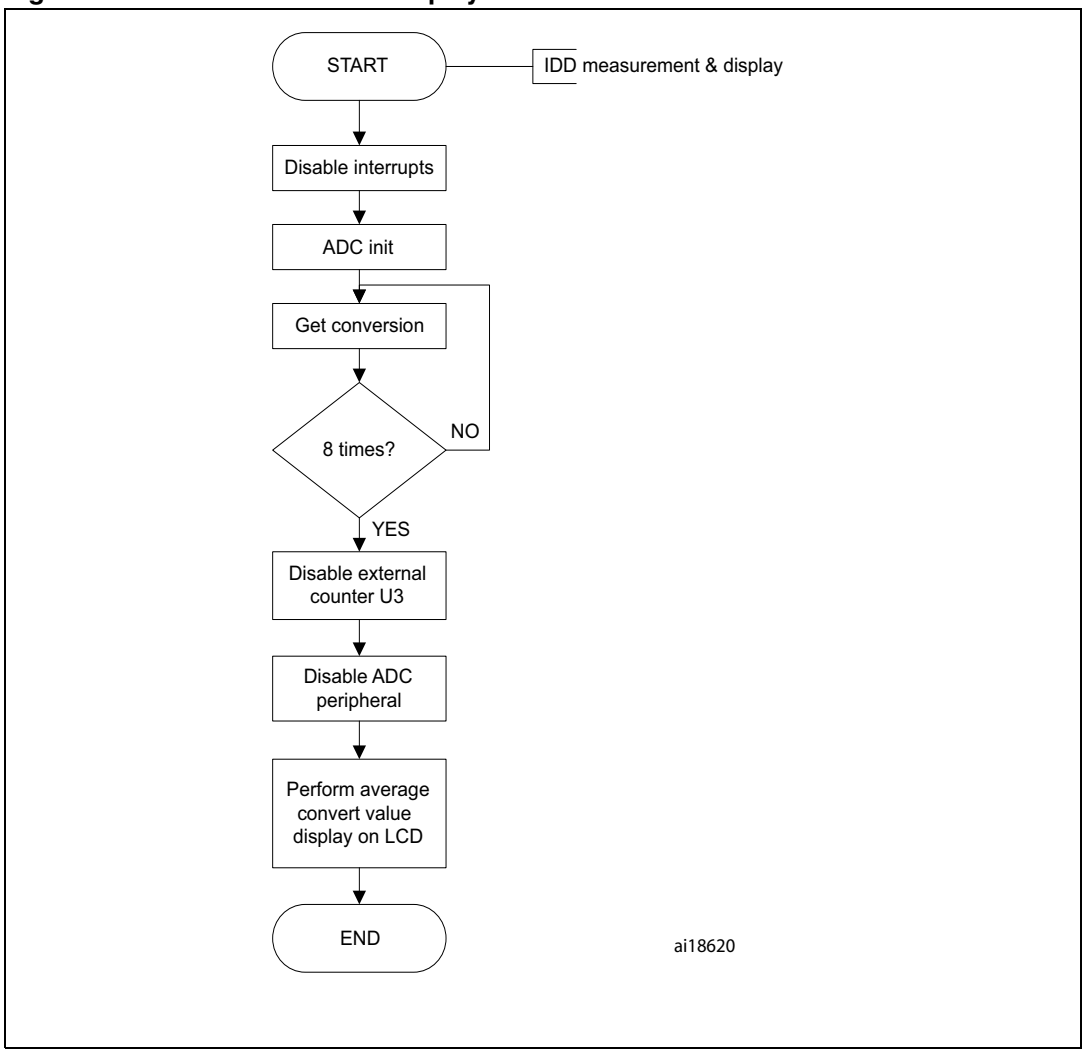
Figure 5. Demo mode sequence



I_{DD} measurement and display

The following flowchart describes the I_{DD} measurement and display steps:

Figure 6. Measurement and display flowchart



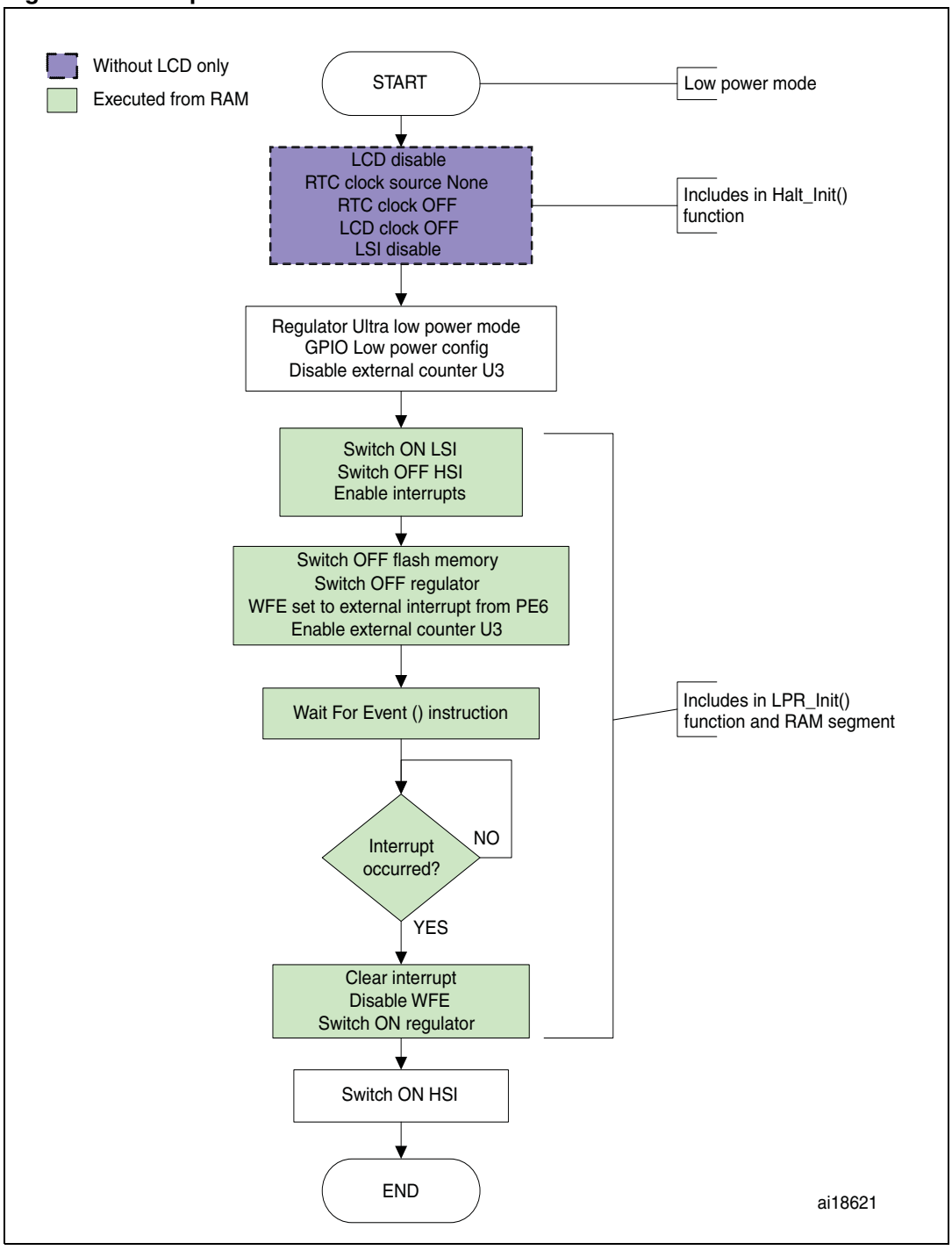
As shown in *Figure 6*, the ADC conversion is performed 8 times in succession and an average value is computed at the end before to be converted and displayed on LCD.

Run, Low power run & Halt modes

For I_{DD} measurement in Run mode, there is no particular setup needed other that performed during the STM8L152 power on initialization. For this function, the application goes directly to I_{DD} measurement and display routine.

For other functions such as Low power run (with or without LCD) and Halt, here are detailed the flowcharts of the specific device configuration:

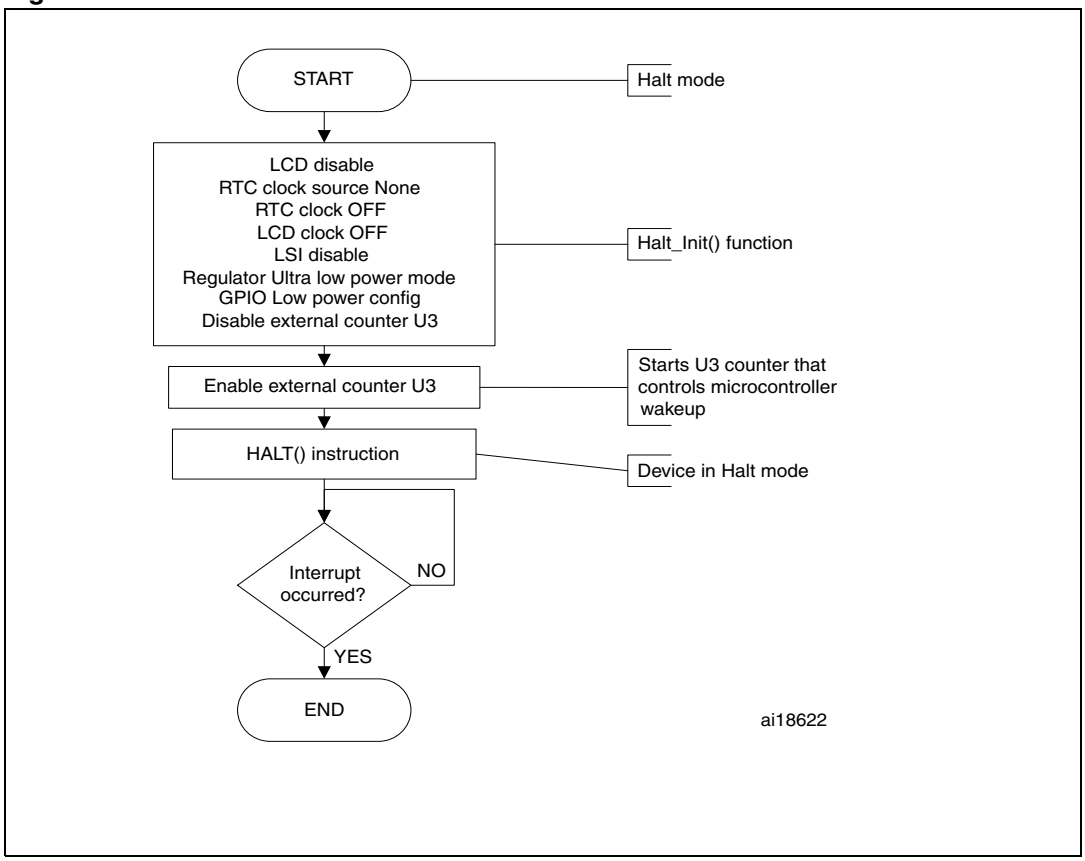
Figure 7. Low power run mode flowchart



In *Figure 7* the part of the flowchart in purple shading only concerns Low power run mode without LCD for which it is useful to disable additional modules like RTC and LCD. The part in light green shading is executed from RAM so that Flash memory and regulator can be switched OFF and thus save more power as the LSI oscillator also switched to be the main clock source.

In Halt mode, the device reaches a deeper level of energy saving level by disabling the oscillators. The device is woken up from this mode by an external interrupt generated by the U3 counter.

Figure 8. Halt mode flowchart



3 Conclusion

A multitude of new mobile, communications-based, wireless, entertainment and computing applications being developed for tomorrow's markets need more and more performance and longer times between battery recharging. STM8L both combines high performance core and ultra-low-power consumption modes. This example allows you to evaluate the current consumption of the STM8L microcontroller in various operating conditions and to demonstrate its low-power capabilities by directly providing the consumption value to STM8L-DISCOVERY users on the LCD panel.

With this example, STM8L-DISCOVERY provide a very low cost environment that can be used for additional development projects where device consumption and application autonomy take on their full meaning. It can be a useful starting point that can easily expanded to investigate other aspects of the user's target application.

4 Revision history

Table 2. Document revision history

Date	Revision	Changes
16-Sep-2010	1	Initial release

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